PART A

1. **What is composite section of prestressed concrete? [A/M 16]**
   A composite section in context of prestressed concrete members refers to a section with a precast member and cast-in-place (CIP) concrete.

2. **Define – composite construction**
   Composite construction of providing monolithic action between prefabricated units like steel beams, precast reinforced or prestressed concrete beams and cast in situ concrete. This method is found to provide a greater structural efficiency compared with the conventional methods of construction. The resulting structure formed by two or more materials is called composite construction.

3. **Define – spandrel beam**
In steel or concrete construction, the exterior beam that extends from column to column and marks the floor level between stories is defined as spandrel beams. In buildings of more than one story, the spandrel is the area between the sill of a window and the head of the window below it. In steel or reinforced-concrete structures, a deep spandrel beam may span across this area. The flat plates are provided with spandrel beams at the edges. These beams stiffen the edges against rotation.

4. **Where are the composite constructions used?** (N/D 16)

In a composite construction, precast prestressed members are used in conjunction with the concrete cast in situ, so that the members behave as monolithic unit under service loads.

5. **Define – propped construction** (N/D 16)

The dead-load stress developed in the precast prestressed units can be minimized by propping them while casting the concrete in suit. This method of construction is termed as propped construction.

6. **Define – unpropped construction**

If the precast units are not propped while placing them in situ concrete, stresses are developed in the unit due to the self-weight of the member and the dead weight of the in suit concrete. This method of construction is termed as unpropped construction.

7. **Give the advantages of precast prestressed units.**

The advantages of precast prestressed units are:

a) The C/S is more efficiently utilized when compared with a RC section.
b) Effective saving in use of materials.
c) Improves the ability of material for energy absorption under impact load.
d) The economy of PSC is well established for long span structures.
e) There is considerable saving on the quantity of materials used in it.

8. **What is circular prestressing?** [A/M 16]

The term refers to prestressing in round members such as tanks and pipes. Liquid retaining structures such as circular pipes, tanks and pressure vessels are admirably suited for circular prestressing.

9. **What are the advantages of prestressed concrete sleepers?**

The advantages of prestressed concrete sleepers are:

a) It is economical.
b) Full cross-section of member is utilized.
c) Increases durability.
d) Reduces corrosion of steel.
e) Increase in shear capacity.

10. **What are the advantages of prestressed composite sections?** [A/M 16]

The advantages of prestressed composite sections are:

a) Savings in form work
b) Fast-track construction
c) Easy to connect the members and achieve continuity.
11. **How the composite action between the precast and cast insitu concrete is achieved?**
In structural systems prestressed concrete is often combined with other materials such as reinforced concrete for the sake of economy and efficiency. The resulting structure formed by two or more materials is composite construction. So the combination of two materials acting as a monolithic action called composite action in prestressed concrete structures.

12. **Explain the effect of differential shrinkage on a composite member.**
The in-situ concrete in a composite beam is of relatively low grade and has correspondingly higher water cement ratio. On the other hand, the precast prestressed concrete is of higher grade and most of its shrinkage has already occurred before the placement of in-situ concrete. Consequently, the in-situ concrete shrinks more than the precast concrete.

13. **Write the assumption in analysis of ultimate stress in composite construction.** [N/D14]
The analysis at ultimate is simplified by the following assumptions.
   a) The small strain discontinuity at the interface of the precast CIP portions is ignored.
   b) The stress discontinuity at the interface is also ignored.

14. **Explain the effect of deflection on a composite member.**
The deflections at different stages in the precracking range of the composite beam may be determined with reasonably accuracy using the linear elastic theory. The deflection depends upon the method of construction and the stage of loading. In a composite beam forward by the combination of precast prestressed concrete and in-situ concrete, the moment of inertia of only the precast component should be taken into account in computing the initial and final chamber due to prestress.

15. **Explain the effect of shear strength on a composite member.**
A composite beam comprising prestressed concrete and plain or reinforced concrete may fail in one of the following ways; it may fail in vertical shear like a conventional non composite beam. In order to prevent shear failure it should be verified that the design ultimate shear does not exceed the ultimate shear strength in accordance with the code provisions.

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**Part – B (16marks)**

1. A precast pretensioned beam of rectangular section has a breadth of 100mm and depth of 200mm. The beam with an effective span of 5m is prestressed by the tendons with their centroids coinciding with the bottom kern. The initial force in the tendons is 150kN. The loss of prestress is 15%. The top flange width is 400mm with the thickness of 40mm. If the composite beam supports a live load of 8kN/m². Calculate the resultant stresses developed if the section is propped and unpropped. [N/D14]
A composite T beam is made up of pretensioned rib of 100mm wide and 200mm deep and a cast insitu slab of 400mm wide and 40mm thick. Having the modulus of elasticity as 28kN/m², if the differential shrinkage is 100 x 10^{-6} determine the shrinkage stresses developed in precast and cast insitu units.[A/M16]
3. A composite T-girder of span 5 m is made up of a pre-tensioned rib, 100 mm wide by 200 mm
depth, with an in situ cast slab, 400 mm wide and 40 mm thick. The rib is prestressed by a straight
cable having an eccentricity of 33.33 mm and carrying initial force of, 150 kN. The loss of prestress is
15%. Check the composite T-beam for the limit state of deflection if its supports an imposed load of
3.2 kN/m for (i) unpropped (ii) propped. Assume modulus of Elasticity of 35 kN/mm² for both precast &
insitu cast elements. [A/M15]

Modulus of elasticity, \( E = 35 \times 10^3 \) N/mm²

\[
deflection\ to\ prestress = \left( \frac{P_e t^2}{8 E I} \right) = \left[ \frac{150 \times 10^3 \times 33.33 \times 5000^2}{8 \times 35 \times 10^3 \times 667 \times 10^5} \right]
\]

= 6.7 mm (upward)

Effective deflection after losses = (0.85 \times 6.7) = 5.7 mm

Deflection due to self-weight of precast beam

\[
= \left( \frac{5g t^4}{384 E I} \right) = \left[ \frac{5 \times 0.48 \times 500^4}{384 \times 35 \times 10^3 \times 667 \times 10^5} \right] = 1.7\ mm
\]

Deflection of precast beam due to self-weight of cast in situ slab

\[
= \left( \frac{(1.7 \times 0.384)}{0.48} \right) = 1.34\ mm
\]

Deflection of composite beam due to live load

\[
= \left( \frac{5 \times 3.2 \times 500^4}{384 \times 35 \times 10^3 \times 1948 \times 10^5} \right) = 3.83\ mm
\]

Deflection of composite beam due to self-weight of cast in situ slab

\[
= \left( \frac{5 \times 0.384 \times 500^4}{384 \times 35 \times 10^3 \times 1948 \times 10^5} \right) = 0.47\ mm
\]

(a) Unpropped construction:
Resultant deflection under service loads = (-5.7 + 1.7 + 1.34 + 3.83)

= 1.17 mm

(b) Propped construction:
Resultant deflection under service loads = (-5.7 + 1.7 + 0.47 + 3.83)

= 0.30 mm

According to IS: 1343, the maximum permissible deflection under service loads is
limited to a value of (span/250) = (5000/250) = 20 mm.

However, this value includes the long-term effects of creep and shrinkage. If the
creep coefficient is assumed to be 3.0, final resultant deflections for unpropped and
propped constructions are 3.51 and 0.9 mm respectively, which are well within the
permissible limits specified in the code.

4. Design the continuous prestressed beam of two spans (AB = BC = 15m) to support a udl of 10kN/m.
Tensile stresses are not permitted in concrete and the compressive stress in concrete is not to exceed
15kN/mm². Sketch the details of the cable profile and check for stresses developed at the support and
span sections. [N/D 14]
Since the ends A and C are simply supported,
\[ M_{AB} = M_{CB} = 0 \]

Also
\[ k = 1 \text{ and } M_{BA} = M_{BC} = M_B \]

\[ K_{BA} = K_{BC} = -\frac{6P}{L^2} \int exdx \]

\[ = -\frac{6 \times 360}{10 \times 10} \left[ -(0.05) \times 10 \times 5 \right] = 54 \text{ kN m} \]

\[ \therefore 4M_B = (2 \times 54) = 108 \text{ kN m} \]

S.M. at B is
\[ M_B = 27 \text{ kN m} \]

Resultant moment at B due to prestress = (P.M. + S.M.)
\[ = \left[ -(360 \times 0.05) + 27 \right] = 9 \text{ kN m} \]

\( w_d = (1.50 + 0.72) = 2.22 \text{ kN m} \)

Moment at B due to loads
\[ = \left( \frac{w_d L^2}{8} \right) = -\left( \frac{2.22 \times 10^2}{8} \right) \]

\[ = 27.75 \text{ kN m} \]

\[ \therefore \text{Total resultant moment at } B = (9 - 27.75) = -18.75 \text{ kN m} \]
5. i) Explain the types of composite construction with neat sketch

(ii) Explain the precast prestressed concrete stresses at serviceability limit state.
The most common type of composite construction consists of a number of precast prestressed inverted T-beams, placed side by side and connected by a continuous top slab of in situ concrete\(^1\). This type of construction is widely used in the construction of bridge decks. Transverse prestressing is also used to develop monolithic action in the lateral direction. The dead-weight of the deck can be considerably reduced by using voids or light-weight longitudinal cores in the space between the precast prestressed units. For large-span composite bridge decks of spans exceeding 30 m, the commonly used precast prestressed concrete units consist of I, unsymmetrical T or box sections\(^2\). The concrete cast in situ forms the deck slab, interconnecting the precast units. Typical cross-sections of bridge decks with different types of precast units are compiled in Fig. 14.1(a).

The precast prestressed I and T-beams have been standardised by the Cement and Concrete Association\(^3\) for use in the construction of bridge decks of span varying from 7 to 36 m. Standard I and T units are extensively used as highway bridge beams in U.S.A.\(^4\)

Typical cross-sectional details and the sectional properties of the standard inverted T-beams developed by the Ministry of Transport and Cement Concrete Association, London, is shown in Fig. 14.1(b) and Table 14.1.

<table>
<thead>
<tr>
<th>Number</th>
<th>Overall depth mm</th>
<th>Area ( \text{mm}^2 )</th>
<th>Height of centroid above bottom fiber mm</th>
<th>Section moduli ( \text{mm}^3 \times 10^6 ) Top fibre</th>
<th>Bottom fibre</th>
<th>Dead load kN/m</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>640</td>
<td>284,650</td>
<td>220</td>
<td>24.72</td>
<td>47.17</td>
<td>6.71</td>
</tr>
<tr>
<td>M2</td>
<td>720</td>
<td>316,650</td>
<td>265</td>
<td>35.64</td>
<td>61.04</td>
<td>7.46</td>
</tr>
<tr>
<td>M3</td>
<td>800</td>
<td>348,650</td>
<td>310</td>
<td>46.96</td>
<td>74.31</td>
<td>8.21</td>
</tr>
<tr>
<td>M4</td>
<td>880</td>
<td>323,050</td>
<td>302</td>
<td>43.41</td>
<td>85.95</td>
<td>7.61</td>
</tr>
<tr>
<td>M5</td>
<td>960</td>
<td>355,050</td>
<td>357</td>
<td>59.39</td>
<td>106.33</td>
<td>8.37</td>
</tr>
<tr>
<td>M6</td>
<td>1040</td>
<td>387,050</td>
<td>409</td>
<td>75.39</td>
<td>116.23</td>
<td>9.12</td>
</tr>
<tr>
<td>M7</td>
<td>1200</td>
<td>393,450</td>
<td>454</td>
<td>66.46</td>
<td>123.16</td>
<td>8.52</td>
</tr>
<tr>
<td>M8</td>
<td>1200</td>
<td>393,450</td>
<td>454</td>
<td>87.39</td>
<td>143.57</td>
<td>9.27</td>
</tr>
<tr>
<td>M9</td>
<td>1280</td>
<td>425,450</td>
<td>512</td>
<td>108.09</td>
<td>161.96</td>
<td>10.02</td>
</tr>
<tr>
<td>M10</td>
<td>1360</td>
<td>457,450</td>
<td>568</td>
<td>128.65</td>
<td>179.36</td>
<td>10.78</td>
</tr>
</tbody>
</table>
The use of prestressed concrete tie beam in a reinforced concrete truss considerably reduces the cross-sectional dimensions of the bottom chord member, which is subjected to high degree of tension in the case of large span trusses. Reinforced and prestressed concrete trusses are generally used for spans ranging from 18 to 36 m and this form of construction is ideally suited for industrial structures.

The dead load stress developed in the precast prestressed units can be minimised by propping them while casting the concrete in situ. This method of construction is
6. A precast pre-tensioned beam of rectangular section has a breadth of 100 mm and a depth of 200 mm. The beam with an effective span of 5 m is prestressed by tendons with their centroid coinciding with the bottom kern. The initial force in the tendons is 150 kN. The loss of prestress may be assumed to be 157%. The beam is incorporated in a composite T-beam by casting a top flange of breadth 400 mm and t = 400 mm. If a composite beam supports a live load of 1 kN/m. Calculate the resultant stresses developed in precast & in-situ cast concrete. (N/D 16) . [N/D 14]

Stress in pre tensioned beam: 

\[ A = 20000 \text{mm}^2 \]

\[ Z = (100 \times 200^2)/6 = 666.67 \times 10^3 \text{mm}^2 \]

Self weight of pre tensioned beam = 0.1 \times 0.2 \times 24 = 0.48 \text{kN/m}

Self weight moment = (0.48 \times 5^2)/8 =
1.5kNm
Stress at top & bottom = ±(1.5x10^6/666.67x10^3) = ±2.25N/mm² Stress in cast insitu slab:
A = 16000mm²
Z = (400x40²)/6 = 10.6x10⁴mm²
Self weight of pre tensioned beam = 0.4x0.04x24 = 3.84kN/m Self weight moment = (0.348x5²)/8 = 1.2kNm
Stress at top & bottom = ±(1.2x10^6/10.6x10^3) = ±1.13N/mm² Stress in composite member

Ixx = (400x40³)/12 - (300x200³)/12 = 1.9x10⁹mm⁴ Zt= (1.9x10⁹)/233.3 = 8.14x10⁶mm²
Zb = (1.9x10⁹)/366.7 = 5.18x10⁶mm²
Live load moment = (1x52)/8 = 2.08kNm
Stress at top = ±(2.08x10⁶/8.14x10⁶) = ±0.25N/mm² Stress at bottom = ±(2.08x10⁶/5.18x10⁶) = ±0.45N/mm²

7. Explain the design and analysis of composite beams

The dimensioning of composite sections involves determining the required size of the composite section using a standard precast prestressed beam of known section properties in order to support the required design service loads. Alternatively, it may become necessary to determine the section modulus of the precast prestressed section for a composite slab of given depth. In either case, formulae relating the section moduli of the precast prestressed and composite section, loading on the member, permissible stresses in the concrete and loss ratio, may be developed by considering various stages of loading as detailed in Sec. 12.1.1.

The critical stress condition generally occurs at the soffit of the precast prestressed element under minimum and maximum moments. Hence, at the stage of transfer, when the minimum moment (self-weight of precast beam) is acting on the precast prestressed beam, the stress condition is,

\[
\left( f_{\text{int}} - \frac{M_{\text{min}}}{Z_b} \right) \leq f_{\text{ct}}
\]  \hspace{1cm} (14.1)
If \( Z_b' \) = section modulus of the bottom fibre of the composite section  
\( M \) = moment acting on the precast part of a composite section during construction  
\( M' \) = moment acting on the composite section which is generally due to imposed loads
\( \eta \) = loss ratio

We then have the stress condition at the soffit of the composite section,

\[
\left(\eta f_{\text{int}} - \frac{M}{Z_b} - \frac{M'}{Z_b'}\right) \geq f_{\text{tw}} \quad (14.2)
\]

By eliminating the prestress \( f_{\text{int}} \) from Eqs 14.1 and 14.2, the required section modulus of the composite section is given by

\[
Z_b' \geq \left[ \frac{Z_b M'}{Z_b(\eta f_{\text{ct}} - f_{\text{tw}}) - (M - \eta M_{\text{min}})} \right] \quad (14.3)
\]

The prestress required at the bottom and top fibres of the precast prestressed beam is computed using the following equations:

\[
f_{\text{inf}} \geq \left[ \frac{f_{\text{tw}}}{\eta} + \frac{M}{\eta Z_b} + \frac{M'}{\eta Z_b'} \right] \quad (14.4)
\]

\[
f_{\text{sup}} \geq \left[ f_a - \frac{M_{\text{min}}}{Z_t} \right] \quad (14.5)
\]

The prestressing force and the corresponding eccentricity are directly obtained by Eqs 12.9 and 12.10.

If it is required to determine the section modulus of the precast prestressed section in a composite slab of given depth, Eq. 14.3 is arranged in an alternative form of the type,

\[
Z_b \geq \left[ \frac{Z_b'(M - \eta M_{\text{min}})}{Z_b(\eta f_{\text{ct}} - f_{\text{tw}}) - M'} \right] \quad (14.6)
\]

The required prestress is calculated using Eqs 14.4 and 14.5 and the stresses developed in the in situ and prestressed components are checked under working loads.